CLAIMS

What is claimed:

1. An x-ray technique-based noninstrusive inspection apparatus (8) which includes:

first and second tunnel sections (12, 14), each having a respective first end (42) and a respective second end (44) opposing the first end thereof, the second tunnel section being located in line after the first tunnel section so that the second end of the first tunnel section is adjacent the first end of the second tunnel section;

first and second conveyor systems (18, 20), the first conveyor system having at least one belt (50), at least partially located within the first tunnel section, which upon, movement, is capable of moving an object (60) from the first end of the first tunnel section to the second end of the first tunnel section, and the second conveyor system having at least one belt (50), at least partially located within the second tunnel section, which, upon movement, is capable of moving an object from the first end of the second tunnel section to the second end of the second tunnel section;

an x-ray source (34) which, when operated, creates radiation within the second tunnel section;

first and second actuation devices (242); and

first and second radiation resistant closure members (56), the first closure member being movable by the first actuation device between an open position wherein the first end of the first tunnel section is open, and a closed position wherein the first closure member closes the first end of the first tunnel section, and the second closure member being movable by the second actuation device between an open position wherein the second end of the first tunnel section is in communication with the first end of the second tunnel section to allow for movement of an object from the first tunnel section to the second tunnel section, and a closed position wherein the second closure member substantially closes off communication between the first and second tunnel sections.

2. An x-ray technique-based nonintrusive inspection apparatus according to claim 1 which includes:

a third tunnel section (16) having a first end (42) and a second end (44) opposing the first end thereof, the third tunnel section being located in line after the second tunnel section so that the second end of the second tunnel section is located adjacent the first end of the third tunnel section;

a third conveyor system (22) having at least one belt (50), at least partially located within the third tunnel section, which, upon movement, is capable of moving an object from the first end of the third tunnel section to the second end of the third tunnel section;

third and fourth actuation devices (242);

third and fourth radiation resistant closure members (56), the third closure member being movable by the third actuation device between an open position wherein the second end of the second tunnel section is in communication with the first end of the third tunnel section to allow for movement of an object from the second tunnel section to the third tunnel section, and a closed position wherein the third closure member substantially closes off communication between the first and second tunnel sections, and the fourth closure member being movable by the fourth actuation device between an open position wherein the second end of the third tunnel section is open, and a closed position wherein the fourth closure member closes the second end of the third tunnel section.

3. An x-ray technique-based nonintrusive inspection apparatus according to claim 2 which includes first, second, third and fourth curtain rollers (54), each being rotatable by a respective one of the actuation devices, wherein the closure members are curtains and each curtain is

secured to a respective curtain roller so as to be rolled onto and from the curtain roller upon rotation of the curtain roller.

4. An x-ray technique-based nonintrusive inspection apparatus according to claim 1 which includes a controller (36) which controls power supplied to the respective actuation devices.

5. An x-ray technique-based nonintrusive inspection apparatus according to claim 4 wherein the controller is programmed to synchronize the actuation devices so that, at least when the x-ray source creates radiation within the second tunnel section, at least one of the first and second closure members is in its respective closed position and at least one of the third and fourth closure members is in its respective closed position.

6. An x-ray technique-based nonintrusive inspection apparatus according to claim 5 wherein the controller turns the radiation source off when at least one of the first and second closure members is not in its respective closed position and at least one of the third and fourth closure members is not in its respective closed position.

7. A method of non-intrusively inspecting an object (60), utilizing an x-ray technique-based nonintrusive inspection apparatus, including:

moving a first radiation resistant closure member (56A), without the object contacting the first radiation resistant closure member, into an open position wherein a first end (42) of a first tunnel section (12) is open, while a second radiation resistant closure member (56B) is in a closed position wherein it closes a second end (44) of the first tunnel section opposing the first end of the first tunnel section;

moving the object, without the object contacting the first radiation resistant closure member, through the first end of the first tunnel section into the first tunnel section while the second closure member remains in its closed position;

moving the first closure member into a closed position wherein the first closure member closes the first end of the first tunnel section;

after movement of the first closure member into its closed position, moving the second closure member, without the object contacting the second radiation resistant closure member, into an open position wherein the second end of the first tunnel section in communication with a first end (42) of a second tunnel section (14);

moving the object, without the object contacting the second radiation resistant closure member, from the first tunnel section into the second tunnel section;

after movement of the object into the second tunnel section, moving the second closure member into its closed position as to substantially close off communication between the first and second tunnel sections; and

radiating the object within the second tunnel section.

8. A method according to claim 7 wherein the confines of the second tunnel section are radiated while the object is moved into the first tunnel section.

9. A method according to claim 7 wherein the first closure member remains in its closed position while the object is moved into the second tunnel section.

10. A method according to any one of claims 7 to 9 wherein the confines of the second tunnel section are radiated while the object is moved into the second tunnel section.

11. A method of non-intrusively inspecting an object (60), utilizing an x-ray technique-based nonintrusive inspection apparatus, including:

scanning a front portion (70, 74) of the object utilizing an x-ray line scanner subsystem (32);

scanning a section (72A) within the front portion utilizing a CT scanner subsystem (34); and

scanning a rear portion (78) of the object, utilizing the x-ray line scanner subsystem, after the section in the front portion is scanned with the CT scanner subsystem.

12. A method according to claim 11 wherein the object is scanned while being moved relative to the x-ray line scanner subsystem and the CT scanner subsystem and the front portion and the rear portion are scanned without altering the direction of movement of the object relative to the x-ray line scanner subsystem and the CT scanner subsystem.

13. A method according to claim 11 or 12 wherein the movement of the object relative to the x-ray line scanner subsystem and the CT scanner subsystem is progressively reduced after the section is scanned by the x-ray line scanner subsystem but before the section is scanned by the CT scanner subsystem.

14. An x-ray technique-based nonintrusive inspection apparatus (8) which includes:

at least one tunnel section (14) having first and second opposed ends (42, 44);

a conveyor system (20) having at least one belt (50), at least partially located within the tunnel section, which, upon movement, is capable of transporting an object from the first end to the second end of the tunnel section;

an x-ray line scanner subsystem (32) which is positioned to scan at a first plane within the tunnel section; and

a CT scanner subsystem (34) which is positioned to scan at a second plane within the tunnel section, wherein the first and second planes are located by a distance of less than 110 centimeters from one another.

15. An x-ray technique-based nonintrusive inspection apparatus (8) which includes:

at least one tunnel section (14) having first and second opposed ends (42, 44);

a conveyor system (20) having at least one belt (50), at least partially located within the tunnel section, which, upon movement, is capable of transporting an object from the first end to the second end of the tunnel section;

an x-ray line scanner subsystem (32) which is positioned to scan at a first plane within the tunnel section; and

a CT scanner subsystem (34) which is positioned to scan at a second plane within the tunnel section, wherein the same belt of the conveyor system conveys the object from first plane to the second plane.

16. An x-ray technique-based nonintrusive inspection apparatus (8) which includes:

a base frame (38); and

a support structure (40) having a lower end (104, 106) secured to the base frame and extending upwardly therefrom;

an x-ray line scanner subsystem (32) mounted to the support structure; and

a CT scanner subsystem (34) rotatably mounted to the support structure.

17. An x-ray technique-based nonintrusive inspection apparatus (8) which includes:

a monocoque base frame (38);

a support structure (40) secured to the base frame; and

a CT scanner subsystem (34) which is rotatably mounted to the support structure.

18. An x-ray technique-based nonintrusive inspection apparatus according to claim 17 wherein the CT scanner subsystem is being rotated a rate of at least 100 revolutions per minute.

19. An x-ray technique-based nonintrusive inspection apparatus according to claim 17 wherein the CT scanner subsystem defines an opening (110) having a cross-dimension of at least 110 centimeters.

20. An x-ray technique-based nonintrusive inspection apparatus according claim 17 wherein the CT scanner subsystem defines an opening (110) and the system includes a conveyor system (20) mounted to the base frame, the conveyor system having a belt (50) which passes through the opening, the belt having a width of at least 90 centimeters.

21. An x-ray technique-based nonintrusive inspection apparatus according to claim 20 wherein the CT scanner subsystem includes a gantry enclosure, a radiation source mounted on one side to the gantry enclosure so that, when the radiation source is operated the confines of the gantry enclosure are radiated, the gantry enclosure being at least partially made of lead.

22. An x-ray technique-based nonintrusive inspection apparatus (8) which includes:

a support frame (10);

a CT scanner subsystem (34) comprising:

first and second spaced gantry plates (154, 156), each having a respective gantry aperture (166, 168) formed therein;

at least one spacer (158, 160, 162) between the gantry plates which, together with the gantry plates, define a partial gantry enclosure (148);

an x-ray source (152) secured to the gantry enclosure at one side thereof so that, when the x-ray source is operated, the confines of the gantry enclosure are at least partially radiated, wherein the gantry enclosure is at least partially of a material which substantially attenuates radiation leakage from the gantry enclosure, the CT scanner subsystem

being mounted to the support frame for rotation about an axis through the first and second gantry apertures; and

a tunnel portion (122) which is nonrotatably mounted to the support frame, the tunnel portion having an end (132) which mates with the gantry aperture in the tunnel portion and being at least partially made of a material which substantially attenuates radiation leakage therefrom.

23. An x-ray technique-based nonintrusive inspection apparatus according to claim 22 wherein the gantry enclosure is at least partially made of a material which substantially attenuates radiation leakage.

24. An x-ray technique-based nonintrusive inspection apparatus according to claim 23 wherein the gantry enclosure includes a respective liner (184, 186), of a material which substantially attenuates radiation leakage, on each of the first and second gantry plates.

25. An x-ray technique-based nonintrusive inspection apparatus according to claim 24 wherein the gantry enclosure includes a lead liner (176, 178, 180), of a material which substantially attenuates radiation leakage, on the spacer.

26. An x-ray technique-based nonintrusive inspection apparatus according to claim 22 wherein the x-ray source includes an x-ray tube and a liner (188), of a material which substantially attenuates radiation leakage, on the x-ray tube.

27. An x-ray technique-based nonintrusive inspection apparatus (8) which includes:

a support frame (10);

a CT scanner subsystem (34) which is rotatably mounted to the support frame, the CT scanner subsystem having a circular outer surface (212);

at least first, second and third pulleys (214, 216, 218) mounted around the CT scanner subsystem to the support frame;

a flexible member (222) running over the first, second and third pulleys, the flexible member having a first section (224) running from the first pulley to the second pulley in a first direction (226) around and over the circular outer surface, and a second section (228) returning from the second pulley over the third pulley back to the first pulley in a second direction (230), opposite to the first direction, around the circular outer surface.

28. An x-ray technique-based nonintrusive inspection apparatus (8) which includes:

at least a first tunnel section (12) having first and second opposed ends (42, 44);

a conveyor system (18,20) operable to move an object (60) through the first end into the first tunnel section;

an x-ray source (34) which, when operated, creates radiation within the first tunnel section;

at least a first actuation device (242); and

at least a first radiation resistant closure member (56) which is movable by the actuation device between an open position wherein the first end of the first tunnel is open to allow for the object to be moved by the conveyor system through the first opening into the first tunnel section without the object contacting the first radiation resistant closure member, and a closed position wherein the first closure member closes the first end of the first tunnel section.

29. An x-ray technique-based nonintrusive inspection apparatus according to claim 28 which includes:

a support frame; and

at least a first curtain roller (54) which is rotatably mounted to the support frame, the first curtain roller being rotatable by the actuation device, wherein the first closure member is a radiation resistant curtain which is secured to the curtain roller so as to be rolled onto and from the curtain roller upon rotation of the curtain roller.

30. An x-ray technique-based nonintrusive inspection apparatus according to claim 29, which includes a tensioning roller (244) rotatably mounted to the support frame and connected to the curtain, the tensioning roller tending to roll the curtain from the curtain roller.

31. An x-ray technique-based nonintrusive inspection apparatus according to claim 30 which includes a spring (248) which is biased between the frame and the tensioning roller so as to tend to rotate the tensioning roller.

32. An x-ray technique-based nonintrusive inspection apparatus according to claim 30 which includes a sheet (246) which has a first portion attached to the curtain roller and rolls with the curtain onto and from the curtain roller, and a second portion attached to the tensioning roller, so as to connect the tensioning roller with the curtain.

33. An x-ray technique-based nonintrusive inspection apparatus according to claim 30 wherein the curtain hangs from one side of the curtain roller and the tensioning roller is located on the same side of the curtain roller as the side of the curtain roller from which the curtain hangs.

34. A method of making a collimator (332) for a detector array (190) of an x-ray technique-based nonintrusive inspection apparatus (8), which includes:

injecting a die (310) with a material;

allowing the material to set within the die to form a body (330); and

removing the body from the die, the body including a support structure (336) and a plurality of septa (334) secured to the support structure.

35. A method according to claim 34 wherein the material includes a first, lead component comprising at least 90 percent thereof.

36. A method according to claim 35 wherein the material includes a second component which provides the material with a strength which is stronger than lead.

37. The method according to claim 36 wherein the second component includes tin.

38. A collimator (332) for a detector array (190) of an x-ray technique-based nonintrusive inspection apparatus (8), which includes:

a body which includes:

a support structure (332); and

a plurality of septa (334) secured to the support structure, wherein center lines (346) of two of the septa located next to one another converge in a first direction (348), but surfaces (342, 344) of the two septa facing one another do not converge in the first direction.

39. A collimator (332) for a detector array (190) of an x-ray inspection apparatus (8), which includes:

a body (330) which includes:

a support structure (332); and

a plurality of septa (334) secured to the support structure, wherein the body is made of a material having a first, lead component comprising at least 90 percent thereof.

40. A collimator according to claim 39 wherein the body includes first and second support structures and the septa are secured between the first and second support structures.

41. An x-ray technique-based noninstrusive inspection apparatus (8) which includes:

a base frame (38);

first tunnel section (12), having a first end (42) and a second end (42) opposing the first end, mounted to the base frame;

a conveyor belt mounting structure (424);

first front and rear conveyor rollers (46, 48) rotatably mounted to the conveyor belt mounting structure; and

a first conveyor belt (50) which runs over the first front and rear conveyor rollers, wherein the conveyor belt mounting structure is mounted to the base frame for at least limited movement, between first and second positions, in a direction (432) in which the conveyor belt moves between the front and rear conveyor rollers, and the conveyor belt

extends at least some distance between the first and second ends through the tunnel section.

42. A method of assembling an x-ray technique-based nonintrusive inspection apparatus (8), from:

(i) a base frame (38) and

(ii) a conveyor apparatus (18, 20) which includes a conveyor belt mounting structure (424), front and rear rollers (46, 48) rotatably mounted to the conveyor belt mounting structure, and a conveyor belt (50) over the front and rear rollers, the method including:

(a) mounting the conveyor belt mounting structure to the base frame.

43. A method according to claim 42 wherein the mounting structure is mounted to the base frame for movement between first and second positions in a direction (432) in which the conveyor belt moves between the front and rear rollers.

44. An x-ray technique-based noninstrusive inspection apparatus (8) which includes:

a base frame (38);

tunneling (12, 14, 16) mounted to the base frame and having a first end (42) and a second end (44) opposing the first end;

an x-ray source (34) which, when operated, creates radiation within the tunneling;

paneling (510) located around the tunneling and the x-ray source so that the paneling and the base frame jointly define a housing (512) around the tunneling and the x-ray source, the housing having an entry aperture (514) in proximity to the first end, and an exit aperture (515) in proximity to the second end of the tunneling, and having an air inlet opening (522);

a fan (538) positioned to draw air through the air inlet opening into the housing, the housing being formed, the entry aperture sealing with the first end of the tunneling to an extent sufficient, and the exit aperture sealing with the second end of the tunneling to an extent sufficient so that the confines of the housing are at a higher pressure than externally of the housing when the fan draws air into the housing.

45. An x-ray technique-based noninstrusive inspection apparatus (8) which includes:

a support frame (10);

a CT scanner subsystem (38) rotatably mounted to the frame, the CT scanner subsystem having a gantry (148) defining at least one air passage (542), and a radiator (534) mounted to the gantry;

a plenum (532) which is mounted to the frame so that the gantry rotates relative to the plenum, the plenum and the gantry jointly defining a confined volume; and

a fan (538) wherein, when the fan is operated, air is directed from the fan into the confined volume, from the confined volume into the air passage, and from the air passage through the radiator.

46. An x-ray technique-based nonintrusive inspection apparatus according to claim 45 which includes:

an air-conditioning unit (528); and

a duct (530) connecting the air-conditioning unit with the plenum so that air is directed from the air-conditioning unit through the duct into the confined volume.

47. An x-ray technique-based nonintrusive inspection apparatus according to claim 45 wherein the gantry defines an enclosure, the air being directed from the air passage into the enclosure in the gantry and from the enclosure in the gantry through the radiator.

48. An x-ray technique-based nonintrusive inspection apparatus according to claim 45 which includes tunneling (12, 14, 16) mounted to the support frame and having a first end (42) and a second end (44) opposing the first end, and paneling (510) located around the tunneling and the CT scanner subsystem so that the paneling and the support frame jointly define a housing (512) around the tunneling and the CT scanner subsystem, the housing having an entry aperture (514) in proximity to the first end, and an exit aperture (515) in proximity to the second end of the tunneling and having an air inlet opening (522) wherein the fan is positioned to draw air through the air inlet opening (522), into the housing, the housing, being formed, the entry aperture sealing with the second end of the tunneling to an extent sufficient so that the confines of the housing are at a higher pressure than externally of the housing when the fan draws air into the housing.

49. An x-ray technique-based nonintrusive inspection system according to claim 41 which includes:

second front and rear rollers (46, 48) mounted to the base frame; and

a second conveyor belt (50) which runs over the second front and rear conveyor rollers, the first rear roller being located adjacent the second front roller and said movement of the conveyor belt-mounting structure parts the first rear roller and the second front roller from one another.